PATENT SPECIFICATION

692,692

Date of filing Complete Specification: Dec. 13, 1948.

Application Date: Dec. 24, 1947. *No. 34137/47.*

Complete Specification Published: June 10, 1953.

Index at acceptance:—Classes 40(v), L22; and 40(vii), AE3(r: s: w), AE4a(1x: 2s2: 4: 5), AE4p(1: 2), AE4v(1a: 3), AE6(c: d: fx: r: s: v).

PROVISIONAL SPECIFICATION

Improvements in and relating to Radio Aerials

I, CHARLES ALEXANDER VIVIAN HEATHCOTE, of 105, The Grove, Ealing, W.5, a British subject, do hereby declare the nature of this invention to be as follows:—

This invention relates to radio aerials, and more especially to aerials used for the transmission and/or reception of radio signals employing carriers of medium, high or very high frequency.

The object of the invention is twofold. Firstly to provide with comparable performance and efficiency, an aerial occupying substantially less space than that required by a normal doublet or other half wave system. Secondly, to provide an aerial having a reasonably uniform response over a comparatively wide band of frequencies, being cheap and robust in construction and of compact size and shape. For these purposes the invention contemplates the use of an arrangement incorporating an aerial in the form of a folded element.

According to the invention a radio aerial system comprises a folded element embodying modification of its physical structure and/or selected feeder connections and/or a method or methods of feed between the element and the transmitter or receiver with which it operates, whereby the band of frequencies to which it can be responsive (within a pre-selected degree of power loss to be tolerated) is greatly increased as compared with a folded element of the same dimensions which does not incorporate such features.

In its preferred form the ends of the aerial element are folded in towards one another so that the aerial assumes a narrow rectangular shape. When folded it may be nearly a quarter wave long at the fundamental frequency. It may be located in a substantially vertical plane, with its greater dimension either vertical or horizontal, or it may be located in a horizontal plane. The abovementioned modification of physical structure which may, according to the invention, be introduced may comprise the provision of a gap in the element at the mid-point of its length, or the insertion at that point of switch means whereby such a gap may be opened or closed at the will of the operator.

The feeder connections which may be employed, according to the invention, with any of the abovementioned folded-element aerials (whether or not provided with a mid-point gap, and whether or not having switch means if such a gap is provided) comprise tuned feeder means, or matched feeder means or both. The matched feeder means may be of fixed type, suitably selected and designed for operation of the aerial system at one pre-arranged frequency; or may be of variable type, e.g. switching means selectively connecting the element to any one of several matched feeding arrangements, allowing the aerial system to operate at or near any one of a plurality of pre-selected spot frequencies, preferably at comparatively widely spaced intervals. The tuned feeder arrangements contemplated may be of any convenient form having (with or without switch means) fixed, pre-set or continuously variable tuning over the band or a part or parts of the band of frequencies in which it is desired that the aerial system shall operate when incorporating tuned feeders of this character.

It can be shown that a folded element, unbroken from end to end, and having an unfolded length of substantially half a wave length at its natural or fundamental frequency of f cycles per second can be adapted, by suitable incorporation of feeder means such as indicated above, to operate over a range of f to $3f$ cycles per second, and that a similar element provided with a gap at mid-point, and combined with such feeder means, can be

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arranged to operate at f and over a range of $3f$ to $5f$ cycles per second, the maximum loss being in no case greater than approximately 2 decibels. When the element is provided with switch means to close its mid-point gap the advantages of both arrangements are available to the operator at will, and accordingly a simple aerial system is provided having an operative frequency range of f to $5f$ cycles per second.

Throughout the range f to $4f$ radiation characteristics akin or similar in type to those of a half wave dipole (i.e. bilobular horizontal radiation if horizontally polarised, circular if vertically polarised) are maintained. Between $4f$ and $5f$ minor side-lobes appear.

Greater frequency ranges, yielding multi-lobular patterns at frequencies beyond $5f$, are also obtainable within the limits of feeder efficiency.

The invention further contemplates arrangements of a plurality of aerial systems such as indicated above, suitably orientated and interconnected, or one or more such aerial systems in combination with suitable director and/or reflector means, adapted to provide directional characteristics, and, if desired, provided with means for selectively varying the directivity of the array at will.

The nature of the invention will be clearly understood from the following description of various forms (given, however, merely by way of example) which it may assume.

In carrying the invention into effect in one convenient manner an aerial system may comprise an element of wire or tube or other conductor with its ends turned back to form a narrow rectangle of length nearly a quarter-wave at the fundamental frequency. The total unfolded loop length L of the element is selected in accordance with the fundamental frequency of the aerial desired, from the approximate formula

$$L = \frac{480}{f},$$

where L is measured in feet, and f is the frequency in megacycles per second. The tips of the inturned ends of the element approach one another closely and constitute the feed point. The spacing or smaller dimension of the loop or rectangle (which has substantial influence on the frequency, tending to lower the frequency when increased) is preferably determined experimentally. In some cases this spacing may be of the order of one fiftieth of the total loop length.

A rectangle loop of the aforementioned character may be supported at a suitable level above the ground with its longer dimension either vertical or horizontal, according to the polarisation of the signals being transmitted and/or received, and in the latter case with the loop in either a horizontal or a vertical plane. The free ends of the element are connected to matching units, e.g. stub-, lumped-circuit-, transformer-, or other convenient matching means, one such unit being provided if the aerial is to operate at one frequency, or a plurality of such units interconnected by switch means allowing an operator to select any one or connect two or more together, e.g. in series, when desired and thereby adjust the operating frequency to any one of several fixed spot frequencies of operation. Arrangements for matched feeder operation at one or more frequencies plus tuned feeder technique for general coverage purposes may be incorporated if desired. The aerial assembly may be connected to its transmitter or receiver by parallel leads, coaxial cable or any other convenient means.

In a modified form of the invention the aerial element and its associated matching units and connecting means are substantially as described above except that at the mid-point of the central portion of the element there is provided a gap electrically separating the element into two halves.

In yet another form of the invention switch means are provided in the aerial gap described in the next preceding paragraph, allowing an operator at will to open or close the gap. The other arrangements of the system remain unchanged.

In further modifications of the invention any of the forms described may be provided with tuned feeder means of any convenient form. These may comprise, for example, a balanced open-wire resonant lineformed of polythene-covered conductors, preferably erected in strained suspension to minimise the number of spreaders required. At very high frequencies variation of feeder length by means of "trombone" tuning adjustments would reduce losses and greatly simplify the feeder tuning and coupling circuits. Any other convenient tuned feeder systems may alternatively or additionally be employed, selected and dimensioned according to the operation conditions and frequency range.

Any of the forms of the invention described may be further modified by folding the aerial element in loops of other shapes than rectangular. Thus for example the turns at the ends of the loop may be semi-circular or sharp-turned

"points," or the element may be shaped as a triangle, double-triangle, diamond or parallelogram with its feed points usually at an apex. Some such variations of shape are more convenient, or may be assumed if it is desired to increase or vary the spacing of the centre of the loop, a process which tends to widen the frequency range of the aerial by extending the low frequency limit.

When tubing is used for the element it may be convenient (e.g. in order to save space and render the aerial compact) for the leads from the feed points of the element to pass through apertures in the end, side or sides of one or more parts of the tube and extend through the interior thereof, being appropriately insulated therefrom.

According to a further feature of the invention an aerial system of any of the above described kinds may be combined with reflector means, (e.g. a flat type, a rotational, sectional or cylindrical parabolic type, a corner type, a conical, biconical, sectoral or pyramidal horn type or other or like reflector of sheet, gauze, netting, gridded or "fishbone" construction), or with one or more directly or parasitically excited elements in the form of director and/or reflector elements, to provide directional sensitivity. Alternatively two more assemblies aforesaid may be combined in appropriate orientation to provide an array with multi-directional characteristics. The reflector and/or other elements may be partially or wholly of metal.

For arrangements comprising a reflector of sheet, gauze, netting, gridded or "fishbone" construction of any type the spacing of the aerial element therefrom may be variable. In any arrangement there may be accommodated with the aerial element such parasitic director and/or reflector elements as may be desired. Furthermore where a corner reflector is used the relative angular disposition of the walls forming the reflector may be variable.

In one convenient arrangement of a plurality of the above described aerial systems to provide a multi-directional array two aerial elements with their larger dimensions horizontal and the loops preferably in a vertical plane are crossed at right angles to one another, running to a central switch means at their mid-points and fed by a 4-wire tuned feeder, one loop being connected across two diagonal feeder wires. A separate cable to the switch means allow either or both loops to be open- or close-circuited at will or continuously, in order to bring one or more or both elements into operation as desired. The switch means may, for example, comprise two separate relay-operated switches, and the operating cable thereto may lead to a rotary or other convenient switch allowing either or both to be operated as desired. Appropriate arrangements of the feeder connections are made to ensure desired phase relationships between the aerial systems and it will be seen that by appropriate arrangements of a selector switch means and the connections thereto the array may be rendered sensitive in any one or more of eight directions separated by 45° intervals. The 4-wire feeder selector switch means may be installed near the operator or located immediately beneath or near to the elements for remote operation from the ground, the latter arrangement permitting the use of a 2-wire or other normal type of feeder between the ground and the selector switch means.

It is a yet further feature of the invention to employ an arrangement of a plurality of aerials as described herein arrayed and operated as above described in order to obtain directional effects. Further, two-wire feeders may be employed, one connected to each apex of two V-arranged elements, instead of the four-wire feeder abovementioned. The limbs of the V-arranged elements need not necessarily be at right-angles to one another and the selector switch, if installed, may be located immediately beneath or near to the elements for remote operation from the ground. Such an array lends itself to incorporation of the tuned and/or matched feeder techniques above described.

In one convenient arrangement according to the invention for directional sensitivity provided by a plurality of folded elements as hereinbefore described, two such loops may be suitably spaced behind one another and parallel to one another, each element being in either a horizontal or vertical plane. The corresponding feed points of the two elements may be connected together and the feeder lines attached to suitable points (e.g. the mid-points) of these connector leads. If desired the conector lines to one element may be crossed to provide anti-phase operation. Alternatively two or more elements may be arranged in co-linear, broadside or end-fire arrays or stacking, or any combinations of such arrangements may be employed. Further any such arrangement may have combined therewith reflector means, and/or reflector and/or director elements operating in any known manner, e.g. driven, non-resonant or self-excited.

In each of the abovementioned arrays

each parasitic element is preferably connected to switch-controlled stub systems or other circuit arrangements designed to provide in those elements current distribution akin to that in the driven element on a selected frequency or band of frequencies, and appropriate phase relationship of operation is secured by suitable adjustment of these connected systems. The various elements may be arranged to operate in different manners at different frequencies or ranges of frequency for which the array is to be used. Where an array comprising a plurality of elements is employed the elements may conveniently be mounted on a boom which may also carry the stub switching relays, and the light tubular or other stubs may be accommodated between the elements by suitable folding. Alternatively adjustable lumped circuits may be employed in place of, or in partial replacement of, the stubs.

In all arrays envisaged suitable means are preferably taken to render the relays, circuit arrangements and connections proof against deterioration from weather and other effects.

In a further modification of the invention applicable to any of the arrangements herein described each element (or one or more of them, where a plurality are employed in combination), instead of being comprised of one loop, may be constructed from a plurality of loops and/or folded formations, preferably parallel to one another and suitably spaced apart, thus providing, in each element so treated, a multi-wire aerial. Such multi-wire construction covers various types and formations, both closed and open-ended.

Aerials comprising elements twisted into two or more turns, or transposed loops, are also contemplated in accordance with the invention.

Further, in any arrangement described the elements and/or conductor leads may be of uniform diameters throughout their length, or may differ in diameter from one another and/or vary in diameter along their length. Like variations of overall cross-section in element and/or conductor arrangements may similarly be employed. As previously mentioned with regard to parasitic arrays, switch means may be provided with multi-wire aerials to allow change-over, as desired, from one form of multi-wire operation to another.

According to a further feature of the invention any of the types of aerial above described may be rendered more compact, (and suitable where only limited space is available to accommodate it) by turning down or in, or by twisting, winding or multiple folding of the turns of the loop or of each loop thereof. Such winding, twisting or folding is preferably effected as non-reactively as possible. Further any of the aforesaid types of aerial may be loaded or inherently tuned to any prearranged frequency or frequencies as desired, e.g. by inserting a capacity and/or inductance or suitable lumped circuits at the mid-point of its length, or between the connecting terminals of the element. Further such loading or tuning may be designed to take effect at certain frequencies without causing undue detriment to the performance of the aerial at others.

Any convenient type of feeding line may be used with any of the aerial arrangements described, for example, in some cases ribbon or webbed type feeders are suitable for the construction of the aerial loop and/or feeder purposes. Feeder screening may be employed if desired.

Where tuned feeds are employed, the circuits or " matching unit " used with any of the above described aerial systems may be arranged *inter alia* to tune the aerial and feeder system to the desired frequency or band of frequencies; to ensure adequate coupling for energy transfer to or from the associated equipment, and to match the input or output circuit of such equipment.

One convenient arrangement may comprise, connected to each feeder terminal a variable condenser, (these two condensers being ganged), and connected between the opposite plates of the condensers a circuit comprising a variable capacity in parallel with an inductance winding, earthed at its centre point, and inductively coupled to another winding receiving power. Such an arrangement provides for series and/or parallel tuning. In an alternative arrangement catering for both tuned and matched feeders, the feeder terminals are connected to the inductance winding by a balanced low-pass filter or network comprising an inductance between each terminal and the corresponding end of the winding, and variable capacities connected between the corresponding ends of these inductances. All such inductances are preferably variable by any suitable means, e.g. being of plug-in type, or separately switched, or progressively shorted by a series of taps. Either arrangement (or modification thereof) may be coupled (e.g. by variable links or tappings) to a transformer, autotransformer, line or other device matching the impedance of the equipment to which it is connected. An electrostatic shield may be provided between the transformer

windings, which may conveniently be located in the housing of the complete matching unit.

If desired means may be provided for switching the coupling line from the aerial side of the matching transformer or other device direct to the feeders, thus bye-passing the tuning circuits and permitting the use of matched feeders between the aerial system and the matching device. Alternatively the tuning circuits may be retained using matched feeders if the leads from the feeder terminals are suitably tapped into, or otherwise properly coupled to, the parallel tuned inductance. In such a case the ganged condenser in series with each terminal lead may be left in or out of circuit, as desired.

If desired any known forms and variations of circuits or arrangements functioning suitably for the purpose or in a similar manner to the above described matching units may alternatively or additionally be employed. Thus split stator or series gap condensers may be used across the lines between the feeder terminals and the ends of the inductance winding connected thereto; and/or a single condenser in place of the two ganged condensers separately connected to the feeder terminals. This single condenser may be left in series with the lead from a feeder terminal, or connected at the centre of, and in series with, the parallel tuned inductance. In the latter method the coil should be given the equivalent of an earthed centre tap.

In place of continuously variable tuning (normally involving two panel controls), plug-in pre-tuned circuit units or switch means selectively connected to pre-tuned coils or circuits suitable for each handling one of a series of selected wave-bands or spot frequencies may be provided. Simplified tuning by trimmer means, e.g. a single variable panel control, may, if desired, be provided for greater efficiency.

Any of the aerial element arrangements described above may, if desired, be suitably mounted for rotation about a vertical axis in order to take advantage of directional characteristics to transmit or receive signals at maximum strength to or from any desired direction and to reduce or exclude signals to or from other directions.

It should be understood that the invention is not restricted solely to the constructional details of the various forms described above since modifications thereof may be introduced as they become desirable in order to carry the invention into effect under different conditions and requirements encountered, without departing in any way from the scope of the invention.

Dated this 24th day of December, 1947.
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COMPLETE SPECIFICATION

Improvements in and relating to Radio Aerials

I, CHARLES ALEXANDER VIVIAN HEATHCOTE, of 26, Bracken Gardens, Barnes, London, S.W.13, formerly of 105, The Grove, Ealing, London, W.5, a British subject, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to radio aerial systems, and more especially to aerial systems used for the transmission and/or reception of radio signals on medium, high or very high frequency radiation.

One object of this invention is to provide with comparable performance and efficiency, an aerial system in which the aerial element occupies substantially less space, i.e. has a shorter main dimension than that required by a normal doublet or other half wave system. Another object is to provide an aerial system having a sensitive and reasonably uniform response at any selected frequency within the range of frequencies over which it is tunable being simple, cheap and robust in construction and of compact size and shape. For these purposes the invention contemplates the use of an arrangement incorporating an aerial element of folded form.

It has been shown previously, see for example "Electronics" January, 1940, pages 26 and 27 and Specifications Nos. 588,044 and 528,817, that aerial elements in the form of elongated loops are capable of resonating in various modes in particular at f and at multiples of f where $2f$ is the frequency at which the length of the elongated loop is substantially one half wave length. While it has been a common practice, in for example Yagi aerials, to use such loops at frequencies of $2f$ and while it has also been proposed

in Specification No. 588,044 to operate at frequencies down to about $1.6f$, using feeders matched at frequency $2f$ and accepting the inevitable mismatch below these frequencies, there has, as far as I am aware, never been used an aerial system incorporating an elongated loop aerial in which the impedance presented from the direction of the aerial to the circuit for coupling or connecting the system to a signal translating device can be made substantially purely resistive at any frequency substantially less than the frequency at which the aerial element behaves as a half wave folded dipole. In fact it has been suggested (see Specification No. 528,817) that the high feed point impedance of a loop at the resonant frequency f makes the use of such a loop at this frequency impracticable.

According to the present invention there is provided a radio aerial system comprising a length or lengths of conductor folded to form an aerial element comprising at least one elongated loop, a circuit provided with means for coupling or connecting said circuit to a signal translating device and connecting means for connecting said aerial element to said circuit, said connecting means being adapted to render the impedance, presented to said circuit from the direction of said aerial element, substantially purely resistive when the aerial element carries standing-wave currents of frequency substantially less than the frequency $2f$, where $2f$ is the frequency at which the said aerial element behaves as a half-wave folded-dipole.

While a simple form of radio aerial system in accordance with the present invention may have a connecting means adapted to render said impedance substantially purely resistive at only a single frequency substantially less than the half wave frequency $2f$, I may also provide systems which are operable at one or more frequencies in addition to the said frequency. Thus I may provide a radio aerial system in which the connecting means is adapted to render the said impedance substantially purely resistive not only at one frequency substantially less than the half wave frequency $2f$ but also at one or more additional frequencies some or all of which may be less than or greater than the said one frequency. As will appear hereinafter, the additional frequency or frequencies may lie anywhere in the range of from $0.5f$ to $3f$ when the loop is a closed loop, while when the loop has a gap substantially opposite the position at which said connecting means is joined thereto the additional frequency or frequencies may lie anywhere in the range of from $3f$ to $5f$. As will also appear hereafter, a system incorporating an aerial element provided with such a gap may be arranged to be operable at any frequency in the range of $3f$ to $5f$ as well as at frequency f.

It will be appreciated that within the given ranges of frequency, the radio aerial system can be arranged to be operable at a plurality of frequencies or over one or more continuous bands of frequency.

In its preferred form the aerial element employed in the invention assumes a narrow rectangular or electrically substantially equivalent shape. It may be approximately a quarter wave long at its fundamental resonant frequency, f. It may be located in any desired plane, e.g. with its greater dimension either vertical or horizontal.

The aerial element may be provided, substantially opposite the position (feed point) at which the said connecting means is joined thereto, with a gap, and strap or switch means may be provided whereby the gap may be opened or closed at the will of the operator. The spacing between the parts of the folded conductor or conductors may be variable.

It can be shown that an aerial element in the form of an elongated loop, unbroken from end to end, and having a total unfolded length (that is to say measured round the loop) of substantially half a wave length at frequency f kilo-cycles per second can be adapted, in combination with a circuit and a connecting means as specified above, to operate at any desired frequency or frequencies over the range of f to $3f$ kilo-cycles per second, and that a similar aerial element provided with a gap substantially opposite the position at which the connecting means is joined thereto, can be arranged to operate at or near frequency f and over a range of $3f$ to $5f$ kilo-cycles per second, the maximum loss in comparison with a half-wave dipole being at no frequency greater than about 2 to 3 decibels. When the element is provided with switch means to close its mid-point gap the advantages of both arrangements are available to the operator at will, and accordingly a simple aerial system is provided having an operative frequency range of f to $5f$ kilo-cycles per second with loss not at any frequency within that range exceeding about 2 to 3 decibels. The figure for maximum loss assumes horizontal polarisation and negligible losses in the connecting means. With vertical polarisation the maximum loss is more dependent upon the height of the aerial and nature of the ground.

and thus may exceed this amount under certain conditions.

Throughout the range f to $4f$ kilocycles per second radiation characteristics resembling those of a half wave dipole (i.e. bilobular horizontal radiation if horizontally polarised, substantially circular if vertically polarised) are maintained with the aerial in its preferred form. Between $4f$ and $5f$ kcs./sec. minor side-lobes usually appear for horizontal polarisation, their nature and magnitude depending upon the aerial element shape employed.

Frequencies below f may be handled at greater losses.

The invention further contemplates arrangements of a plurality of aerial systems such as indicated above, suitably orientated and inter-connected, or one or more such aerial systems in combination with suitable director and/or reflector means, adapted to provide directional characteristics, and, if desired, provided with means for selectively varying the directivity of the array at will.

The invention will be clearly understood from the following description of various forms (given, however, merely by way of example) which it may assume, and this description will be more readily followed by reference to the accompanying drawings wherein:—

Figures 1—3 represent diagrammatically various forms of the invention.

Figure 4 shows in greater detail typical tuned feeder arrangements and adapting circuit in the form of the invention shown in Figure 3.

Figure 5 represents a form of tunable lumped circuit matching unit or feeder tuning network incorporating features alternative to, or in modification of, those shown in Figure 4;

Figures 6—12 represent various alternative shapes of aerial elements which may be used in the invention;

Figure 13 represents an embodiment of the invention which provides for operation at preselected spot frequencies;

Figure 14—17 represent forms of vertical aerial elements which may be used in the invention;

Figure 18 represents a variable directional array of aerial elements to which the invention may be applied;

Figure 19 represents a plan view of the array shown in Figure 18 to explain its directional characteristics;

Figure 20 shows the functions of a feeder switch for use with the array shown in Figure 18 to select the direction of operation of the array;

Figures 21 and 22 represent further arrays to which the invention may be applied illustrating application of the aerial to broadside and end-fire arrays respectively;

Figures 23 and 24 represent a corner-reflector arrangement to which the invention may be applied;

Figures 25 and 26 represent arrays to which the invention may be applied, embodying parasitic elements to provide directivity; Figure 25 showing typical switched phasing arrangements for a parasitic element;

Figures 27—32 represent in expanded form for clarity of illustration, examples of elements of multi-wire construction to which elements the invention may be applied, more especially where it is desired to raise or alter the feed point impedance or improve the bandwidth particularly at frequency f;

Figure 33 represents an element associated with a parabolic reflector;

Figures 34—39 and 40 (a), (b), (c) and (d) represent alternative shapes of the aerial element and details thereof which may, for different reasons, be employed in the invention;

Figures 41 and 42 represent, in circuit diagram, various forms of coupling circuit and impedance adapting means which may be employed in the invention; and

Figures 43 and 44 represent in simplified form antenna loading arrangements which may be employed in the invention.

It is well known that an unfolded half wave dipole suitable for a frequency of $2f$ kilo-cycles per second can be arranged to operate at a frequency of f kcs./sec. by loading the dipole (e.g. by incorporation of one or more suitable inductances), or by associating with the dipole a tuned feeder system. Neither of these modifications is entirely satisfactory, however. A loaded dipole is not readily adjustable in operational frequency, particularly over a continuous range, and the use of a tuned feeder leads to inefficient operation at the lower frequencies, where the larger aerial currents in the vicinity of the current antinode are transferred from the aerial proper to the feeder line or to the coupling arrangements causing a marked drop in sensitivity.

Where, however, the connecting means used in the radio aerial system of the present invention includes a tuned feeder the resultant aerial current distribution is not modified so seriously at the lower frequency, since with this arrangement (which incorporates an elongated loop aerial of similar peripheral length) a current antinode is retained in the aerial element and the attenuation at f in com-

parison with that of the aforesaid unfolded halfwave dipole is in consequence considerably reduced. Further, the tuned feeder may be provided with an adapting circuit whereby the connecting means (i.e. tuned feeder plus adapting circuit) may be controlled to render the impedance presented to my said coupling or connecting circuit substantially purely resistive at any of a wide range of additional frequencies, which therefore becomes available to the operator, the aerial element being of the order of a quarter wave in length at frequency f. The present invention therefore aims at the provision of an efficient antenna free from the abovementioned defects, being sensitive compact and highly flexible in terms of operating frequency.

It can be shown that if a half wave unfolded element suitable for frequency f is folded back at each end, so as to form a narrow loop or rectangle of length approaching half the length of the unfolded wire, and of a suitable chosen width or average width which is small in comparison with its length, it can be voltage-fed at its inturned ends, and will have a fundamental resonant frequency not appreciably different from that of the unfolded wire. In this condition the total peripheral length of the conductor still functions as a half wave element. It should be noted that the resonant frequency is dependent upon both the total length of the element and the width of the loop into which the element is folded, the width when small being the more critical dimension. For a given total length of the element an increase of such width lowers the resonant frequency; by providing for variation of width the resonant frequency may be controlled and adjusted within limits. Since an aerial element as described above has in comparison with the unfolded wire increased inductance (provided the width of the loop is not too small), and reduced capacity, the Q of the aerial is increased and the radiation resistance at the current antinode is reduced, loss at resonance being lowered in comparison with other methods of length compression, owing to the presence on the aerial of this current maximum. The high current portion of the aerial operates relatively undisturbed in its effect as only the minor end-currents of the element are folded back and therefore cancelled. By choice of width and hence of resonant frequency the attenuation of the aerial when operated at f in comparison with the unfolded element can be minimised for an aerial of such small dimensions. Under preferred conditions said resonant frequency will be the same as, or a fraction less than f, depending upon whether or not the loop has a gap at its mid-point.

An element folded into an elongated loop as described above will also resonate at a frequency substantially double the abovementioned fundamental frequency. In this condition the element behaves substantially in the manner of the familiar folded dipole in which each of the two longer sides of the loop functions as a half wave element, the two sides operating mutually in phase, and it can be shown that when operating under such conditions the width of the loop is not an unduly critical factor in determining the resonant frequency $2f$. Thus by suitable selection of the width or the average width the element can be arranged to resonate at its fundamental frequency and at least twice that frequency, the loss in each case being approximately 2 to 3 *db* and 0 *db* respectively.

If the fundamental frequency of a folded element such as described above is identified as f kcs./sec , it can be shown that if such an aerial is properly energised at a frequency increasing from f to $2f$ kcs./sec. loss will decrease from approximately 2 to 3 *db* to zero. It can also be shown that a folded element such as described above can be arranged to operate at any frequency between f and $3f$ kcs./sec., due consideration being given to the connecting means and the transmitter-coupling or -connecting circuit proper requirements for feeding energy into the element as will be discussed more fully below.

It has further been noted that if an aerial element in the form of an elongated loop is open-circuited at a point opposite to the feed point, it will operate satisfactorily, within the limits of tolerable loss, subject to consideration of the connecting means and the coupling or connecting circuit, above-mentioned, at the fundamental frequency of f kcs./sec. and at any frequency between $3f$ and $5f$ kcs./sec. provided side-lobe radiation occurring at frequencies higher than $4f$ kcs./sec. can be regarded as unimportant.

From the above considerations it will be seen that by providing switch means at the gap of an open-circuited element as last described above, whereby the gap can be closed or opened at the will of an operator, the element can be arranged to operate, within the tolerable limits of loss, at any frequency between its fundamental frequency f kcs./sec. and five times that value, $5f$ kcs./sec. It can be shown that signal gain occurs when the

system operates between $2f$ and $5f$ kcs./sec.

It was stated that frequencies below f can be handled with greater losses than those quoted and it will therefore be understood that the operative frequency ranges obtainable are not restricted to those described, but may be determined having regard to the maximum loss that can be tolerated within the frequency limits selected. The ranges previously quoted are therefore given only by way of example, and represent those frequencies at which the greatest aerial sensitivity is secured. Thus the frequency range offered by an unbroken loop may be extended to about $3.5f$ before loss exceeds the 3 decibel limit, but if frequency is reduced down to $0.5f$, for example, the loss rises beyond this figure to some 7 to 9 decibels. Similarly a loop with mid-point gap, normally operating at f and with signal gain between $5f$ and $3f$, may be used down to nearly $2.5f$ before loss exceeds 3 decibels. Frequencies higher than $5f$ yield multi-lobular patterns when horizontal polarisation is employed and are therefore of less interest.

Antennæ of various forms, as will hereinafter appear, designed in accordance with the principles set out above, may be employed.

In carrying the invention into effect in one convenient manner and referring to Figure 1 of the accompanying drawings, an aerial system may comprise an element 1 of wire or tube or other conductor with its ends turned inwardly to form a narrow rectangle of length nearly a quarter-wave at the fundamental frequency. The total unfolded loop length L of the element may be selected for an air-spaced loop in accordance with the fundamental frequency of the aerial desired, from the approximate formula

$$L = \frac{478}{f}$$

where L is measured in feet, and f is the frequency in mega-cycles per second. The tips of the inturned ends of the element approach one another closely and constitute the feed point 2 of the aerial. The spacing or smaller dimension 3 of the loop or rectangle (which has substantial influence on the resonant frequency tending to lower the frequency when increased), is preferably determined experimentally. In some cases this loop width or spacing may be, for a rectangular loop, of the order of one fiftieth of the total loop length for resonance at f, the frequency at which the unfolded wire functions as a half wave element. Experimental choice is usually desirable since the exact spacing dimension or average dimension under all conditions is influenced by a number of factors: chiefly, the loop shape if other than rectangular, the length to diameter ratio of the element conductors, the dielectric constant of the material (if other than air) encompassed by the loop, and whether the element is a closed or open circuit. For a self-supporting element having thick conductors a larger spacing will thus be needed than if thin wires are employed.

A loop shaped element of the aforementioned character may be supported at a suitable level above the ground with its longer dimension either vertical or horizontal, according to the polarisation of the signals to be transmitted and/or received, and in the latter case with the loop in either a horizontal or a vertical plane. The inturned ends forming the feed point of the element are linked with transmitter and/or receiver 7 by parallel-lead or coaxial transmission line 4 and unit 6 which contains a circuit and means for coupling the circuit to the transmitter and/or receiver and also an adapting circuit (which together with the transmission line 4 forms the connecting means) whereby the impedance presented to the circuit may be rendered substantially purely resistive at the operating frequency or frequencies. If convenient, the transmission line may be omitted and the connecting means may take the form of an adapting circuit alone.

In a modified form of the invention the aerial element and its associated matching units and connecting means are substantially as described above except that at the mid-point of the central portion of the element there is provided a gap 5 electrically separating the element into two halves. An example of this modified form of the invention is shown in Figure 2. At frequency f kcs./sec. the element shown in Figure 1 is voltage fed, while that in Figure 2 is current fed. Frequencies other than f kcs./sec. may be employed when using the forms of the invention shown in Figure 1 or 2.

If desired switch means 8 may be provided in the aerial gap 5 (see Figure 3) allowing an operator at will to open or close the gap, as will be described more fully below. The other arrangements of the system remain unchanged.

The embodiments of the invention shown in Figure 2 and 3 are normally provided with a unit 6 as described in connection with Figure 1. If desired the simple aerial elements shown in these figures may be replaced by other forms of

aerial element described or illustrated herein. The tuned transmission line represented by detail 4 may comprise, for example, a balanced open-wire tuned line formed of polythene-covered conductors, preferably erected in strained suspension to minimise the number of spreaders required. For systems intended for operation at very high frequencies the connecting means may be constituted entirely by means of a feeder of adjustable length thereby enabling unit 6 to be simplified with corresponding reduction of losses.

It will be noted that the form of the invention shown in Figure 1 will operate at any frequency between f and $3f$ kcs./sec. When horizontally polarised the form shown in Figure 1 provides bilobular radiation at all operating frequencies, while in the forms shown in Figures 2 and 3 minor side-lobes usually appear at operating frequencies between $4f$ and $5f$ kcs./sec., the nature and extent of same depending upon the aerial loop shape employed.

Figure 13 shows an arrangement of for example three separate connecting means each of which has a matching stub 4(a) arranged to render the impedance presented to a matched transmission line (and consequently to the coupling or connecting circuit) by a tuned line 4(b) substantially purely resistive at a predetermined spot frequency. Switch means 9 enables the required spot frequency to be selected as required. A second switch means would permit one feeder to be used instead of three between the matching arrangements and the transmitter or receiver.

Figures 4, 5 and 41 and 42 show in greater detail various alternative features of devices suitable for use in connection with unit 6.

By suitably adjusting the circuit and adapting means of unit 6 any desired frequency within the full operational range obtainable therefrom can be selected or the system tuned over the range in a continuous manner.

One form of radio aerial system provided by the invention is shown in Figure 4 and comprises variable condensers 10, 11 (preferably ganged together) in the feeder lines, leading to opposite ends of a network comprising a variable condenser 12 in parallel with a coil 13 which may be earthed at its mid-point. A coupling coil 14 is connected to the transmitter and/or receiver. If desired line-balancing meters 15, 16 may be incorporated in the feeder lines, but these are not essential. This simple basic circuit is suitable for tuning to frequencies in the vicinity of those at which the aerial and its connections 4 are in combination resonant.

Any known means of coupling, in place of coil 14, may be employed in this and all other tuning means described, coil 14 being merely an indication that the main inductance 13 is coupled or connected to signal-translating means.

Where an aerial system such as described above is required to have a greater power-handling capacity, this may be improved by increasing the thickness of the conductor forming the aerial element, thereby reducing the larger values of the aerial feed point impedance, as frequency is varied.

Figure 5 represents a more flexible unit than the network shown in Figure 4, the condensers 10, 11, 12 being connected to the coil 13 by adjustable contacts, and the coil being provided at each end with adjustable contact leads 17, 18, or corresponding taps or links, whereby some turns may be short circuited.

To facilitate or permit tuning at frequencies where the feeder impedance seen in the direction of the aerial element has an appreciable reactive component, it may be convenient to connect an inductance in series with each feeder lead or between condensers 10 and 11, said inductive and/or capacitative elements 10, 11 being selected according to requirements. Alternatively, as disclosed in Figure 41 capacitance 36 and/or 39 may be connected between the feeders in place of the series-connected condensers 10 and 11, inductances 37 and 38 being in series with the feeder leads. It may also be convenient to insert capacitance in series with inductance connected between the feeders, in the manner of elements 41 and 13 of Figure 42.

Figure 41 illustrates a tuning unit comprising a main inductance 13, having connected to its extremities a capacitance 39, across which latter is in turn connected a chain formed by two inductances 37 and 38 joined in series by a further capacitance 36, energy being conveyed between said main inductance and signal translating means by a winding 14. Unless, as shown in Figure 5 and described above, connections to a feeder network are taken from points of the main inductance of this circuit, the feeder leads may be attached directly to the terminals shown, i.e. across capacitance 36. In the latter arrangement a network formed by inductances 37 and 38 and capacitance 36 connects to points of said main inductance, which is tuned by capacitance 39. Alternatively and with similar feeder connection, the said network may be taken to include capacitance 39,

thus forming a pi network or low pass filter connected to the extremities of an untuned coupling inductance 13.

In Figure 42 energy is conveyed as aforesaid by a winding 14 associated with a main inductance 13, there being connected at the centre of said main inductance a capacitance 41, and to the outer extremities of the main inductance a capacitance 40. Connections to a feeder network may be taken, as aforesaid, from points of the main inductance, as shown in Figure 5. If the condenser 41 is not of the 3 plate, split stator or series gap type, enabling its central point or rotor to be earthed, if desired, the inductance 13 is preferably balanced symmetrically with respect to earth by other means. Capacitance 41 can be used to series-tune the main inductance, whether or not the parallel condenser 40 is selected or employed for parallel tuning same.

In any of the described arrangements of circuit and connecting means, any inductance or tuning unit, or the complete matching unit, may be interchangeable with a like unit, each unit being designed for use over a specified portion of the full frequency range for which the aerial system is operable.

Any of the forms of the invention described may be further modified by folding the conductor or conductors of the aerial element to form loops of shapes other than rectangular. Examples of different shapes which may be employed are illustrated in Figures 6 to 12. Thus for example the turns at the ends of the loop may be semi-circular (Figure 7) or sharp-turned " points " (Figure 8), or the element may be shaped as an elongated triangle (Figures 9 and 10) elongated double-triangle (Figure 11) or elongated diamond (Figure 12) with its feed points usually at an apex. Some such variations of shape are more convenient, or may be assumed, if it is desired to increase the spacing of the centre of the loop, a process which can be utilised in certain circumstances to widen the frequency range of the aerial by extending its low frequency limit, for a given loss level. Increased end portions, as shown in Figures 34 to 36 may be desirable for improving end-fire radiation sensitivity at certain frequencies.

In any of these forms of antenna element a gap, with or without switch means, may be provided at the mid-point of the element, as previously described. The central spacing of the upper and lower limbs of the element is preferably determined experimentally for the desired fundamental resonant frequency or overall frequency performance of the loop.

When tubing is used for the element it may be convenient (e.g. in order to save space and render the aerial compact) for the leads from the feed point of the element to pass through apertures in the end or ends, side or sides of one or more parts of the tube and extend through the interior or part thereof, being insulated from the element where appropriate. Examples of such arrangements, more especially suitable for vertically polarised aerials, are shown in Figures 14 to 17.

According to a further feature of the invention an aerial system of any of the above described kinds may be combined with reflector means and/or with one or more non-resonant, driven or parasitically excited elements in the form of director and/or reflector elements, to provide directional sensitivity.

One example of a fixed aerial element array having variable directional sensitivity for multi-directional operation is shown in Figures 18 to 20. This has bi-directional sensitivity in any opposing pair of eight directions according to the method of connection employed and comprises two folded elements 1*a*, 1*b* (each of which may be of form similar to that shown in any of Figures 1 to 4 or 6 to 12 or 34 to 39) arranged for horizontal polarisation and preferably mounted in vertical planes at right angles to one another. A box 17 centrally of both elements may house two separate switches actuated, when desired, through the lead or leads 18. The elements are separate from one another and have no junction in the box 17, each element connecting to one of said switches as shown and having a gap switch as at 8, Figure 3. When the elements are not of the switched variety, being, for example, as shown in Figures 1 and 2, the box 17 will serve merely as an insulating and positioning device for the wires of the two elements. Referring to Figure 19 which shows the array in plan view it will be seen that element AB alone has NE—SW sensitivity, element CD alone has NW—SE sensitivity, while simultaneous operation of both elements with suitable phasing arrangements of the signals therein will provide N—S or E—W working. Such phasing is a matter of inter-feeding connection only and does not necessarily involve the introduction of extra lengths of feeder to produce delay effects.

A form of selector feed switch which may be employed with a four-wire feeder to facilitate control of the directional sensitivity of the array is indicated in Figure 20, comprising an insulated rotor arm 19 of which opposite end contacts

ride against arcuate metal contacts separately connected to the aerial leads shown as a, b, c and d in Figures 18 and 20. The end contacts of the rotor arm are connected to the remainder of the system by a two-wire feeder 4 shown arrowed, and it will be seen that rotation of the arm 19 allows the leads 4 to be connected to either or both elements in various ways. For example, in the switch position illustrated, the leads are respectively connected to b and c on one side, and to a and d on the other side, both elements thus being simultaneously connected across the said leads. Consideration of the relative phasing of the currents in the two elements will show that E—W sensitivity is provided.

If desired a goniometer arrangement of the tuning circuits may be employed in place of the switch means shown in Figure 20.

Examples of bi-directional aerial arrays embodying the invention are shown in Figures 21 and 22. Figure 21 is a side elevational view of two aerial elements such as shown in Figure 3, with longer dimensions horizontal or vertical, connected in phase in the broadside manner. Figure 22 shows in perspective two like elements mounted in parallel vertical planes. This array can also be oriented to become vertically polarised. The two elements can be fed 180° out of phase (as illustrated in Figure 22) to provide " end-fire " operation of the array. Thus two or more elements may be arranged in co-linear, broadside or end-fire arrays or any combination of such arrangements may be employed. Further any such arrangement may have combined therewith reflector means, and/or reflector and/or director elements operating in any known manner, e.g. driven, non-resonant, or parasitically excited.

An example of an aerial incorporating a specular reflector is shown in Figures 23 and 24, illustrating an aerial element such as shown in Figure 3 associated with a corner reflector 20, in the form of a V-shaped metallic sheet, grid or netting. The radiation resistance of the aerial element is influenced by the spacing S of the element from the reflector, and this spacing is therefore preferably variable, e.g. by mounting the element at the end of tubular feeders of variable length extending through an aperture in the reflector. These feeders may, if desired, be provided with calibrated markings to indicate spacing to be set in terms of radiation frequency in use, or alternatively a calibrated spacing control device may be provided.

The reflector is preferably of meshed grid or fishbone construction, or of gauze, to reduce wind resistance, and the corner angle of the reflector may be adjustable in addition to, or alternatively to, variable spacing S of the element therefrom. If desired the aerial element 1 may have associated therewith one or more parasitic elements, as described herein.

Aerial arrays embodying the invention may comprise a driven element similar, for example, to any shown in Figures 1 to 4 or 6 to 12 associated with parasitic elements of like construction. Each parasitic element is connected to switch controlled stub systems or other circuits designed to provide current distribution similar to that in the driven element at any one or more selected frequencies or frequency band e.g. Figure 25. The phase relationships for the desired parasitic action are secured by suitable adjustment of the individual stubs or circuits. The element spacings may be of any desired values according to requirements.

One example of a parasitic array according to the invention is shown in Figure 25 and 26. Figure 25 shows a parasitic element with stub relay switches for selected frequencies of operation, while Figure 26 shows an array of two such parasitic elements in association with a driven element, all set in vertical planes. The elements are supported upon a common boom which also carries the stub relays and accommodates light tubular stubs folded therebetween as shown. Circuits incorporating adjustable lumped reactants may be used in place of or in partial replacement of the stubs, i.e. to give the phase relationships for the desired parasitic action, and the looped aerial elements may, if desired, be set in a horizontal plane rather than in vertical planes.

The various elements may be arranged to operate in different manners at different frequencies or ranges of frequency for which the array is to be used.

In all arrays envisaged suitable means are preferably taken to render the relays, circuit arrangements and connections proof against deterioration from weather and other effects.

In a further feature of the invention applicable to arrangements herein described each antenna element (or one or more of them, where a plurality are employed in combination), instead of being comprised of one loop, may be constructed from a plurality of loops and/or folded formations, preferably parallel to one another and suitably spaced apart, thus providing, in each element so treated, a multi-wire aerial. Such multi-wire construction covers various types

and formations, both closed and open-ended, suitable for continuously variable and spot frequency working respectively.

Aerial elements in which the elongated loops are twisted into two or more turns or transposed loops may also be employed in accordance with the invention.

Examples of such multi-wire constructions are illustrated in Figures 27 to 32 herewith, showing in perspective expanded views of various multi-folded aerial elements which may be used in the invention. Any of these forms of elements may, if desired, be used at frequency f, but "closed" multi-wire loops (of the Figure 29 or 30 type) may also be employed at any other frequency up to $3f$ as required. If desired switches may be incorporated in a multi-wire element (e.g. as shown in any of Figures 27 to 32) to allow it to be modified, by switching, to a different form of element. Thus, for example, in Figures 29 and 30 switches may be arranged to provide a gap at the mid-point of each of the folded loops (as previously described for a single loop element) to permit operation over a larger frequency range. Since suitably arranged multi-wire construction is well known to give modified feed -point impedance and improved bandwidth to a conventional unfolded dipole, it will be clear to those versed in the art that the main advantage of these elements lies in providing compact wide-band aerials for use in accordance with the invention with non-resonant feeders at frequency f.

Further, in any arrangement described the elements and/or conductor leads may be of uniform diameters throughout their length, or may differ in diameter from one another and/or vary in diameter along their length. Like variations of overall cross-section in element and/or conductor arrangements not having a circular cross-section may similarly be employed.

A manner in which the aerial element may be associated with a parabolic reflector is shown in Figure 33. The element is preferably located at or near the focal distance S from the reflector which is preferably not greater than half the radius R of the mouth of the reflector, and preferably equal to or greater than $\frac{1}{4}\lambda$, where λ is the wavelength of the fundamental resonant frequency of the assembly. The aerial may comprise a simple driven element or may incorporate parasitic elements (as above described) or a hemispherical reflector shield.

The aerials of the invention are suitable for short-wave reception over a wide frequency band. Suitable simple arrangements being shown in Figures 1 to 3. For ease of operation unit 6 should be located conveniently near to the receiver. Alternative shapes of aerial element which may be used in accordance with the invention, are shown in Figures 34, 35 and 36, the elements of Figures 34 and 35 being shown, in side view, in a vertical plane, and that in Figure 36 being shown, in perspective, in a horizontal plane. Other available constructions of the aerial element are shown in Figures 37 and 38, where the element is of twisted or crossed form to conserve space and/or to strengthen the aerial. In Figure 39 is illustrated yet another form of element which may be employed where installation requirements limit the maximum span of aerial which may be set up.

According to a further feature of the invention any of the types of aerial above described may be rendered more compact; (and suitable where only limited space is available to accommodate it) by turning down or in, or by twisting, winding or multiple folding of the span-end portions of the loop or of each loop thereof. Examples of the manner in which the end portions of an element may be thus formed are illustrated in Figure 40 (a), (b), (c) and (d). Such winding twisting or folding is preferably effected as non-reactively as possible.

In any of the arrangements above described the lowest operational resonant frequency of the antenna element may be reduced by loading or tuning the loop element itself, e.g. by fixed or variable capacity which may be permanently in circuit, or switchable into and out of circuit as desired, or short-circuited by switch means. Examples of simple capacitative loading which may be employed are illustrated in Figures 43 and 44. Alternatively, and independent of the tuning unit circuits, suitable lumped circuits may be employed in place of such simple capacitance, whereby said loading or tuning may be designed to take effect at certain frequencies without causing undue detriment to the performance of the aerial at others.

Any convenient type of feeding line may be employed in any of the aerial arrangements described. For example, in some cases ribbon or webbed type feeders, or conductors separated or mutually supported in webbed or partially webbed manner, are suitable for the construction of the aerial loop or loops and/or feeding purposes.

The lumped inductances used are preferably variable by any suitable means, e.g. being of plug-in type, or switched, or progressively shorted or selected (see Figure 5). Any of the tuning arrange-

ments described (or modifications thereof) may be coupled (e.g. by variable links or tappings) to a transformer, autotransformer, line or other device matching the impedance of or suiting the equipment to which it is connected.

It will be appreciated that besides any convenient form of lumped inductance any convenient form of lumped capacitance may be used in the various circuits disclosed herein. For example split stator, 3 plate or series gap condensers may be used in place of the ordinary capacitors shown in the drawings.

Any of the aerial element arrangements described above may, if desired, be suitably mounted for rotation about a vertical axis in order to take advantage of directional characteristics to transmit or receive signals at maximum strength to or from any desired direction and to reduce or exclude signals to or from other directions.

It should be understood that the invention is not restricted solely to the constructional details of the various forms described above since modifications thereof may be introduced as they become desirable in order to carry the invention into effect under different conditions and requirements encountered, without departing in any way from the scope of the invention.

What I claim is:—

1. A radio aerial system comprising a length or lengths of conductor folded to form an aerial element comprising at least one elongated loop, a circuit provided with means for coupling or connecting said circuit to a signal translating device and connecting means for connecting said aerial element to said circuit, said connecting means being adapted to render the impedance, presented to said circuit from the direction of said aerial element, substantially purely resistive when the aerial element carries standing-wave currents of frequency substantially less than the frequency $2f$, where $2f$ is the frequency at which the said aerial element behaves as a half-wave folded-dipole.

2. A radio aerial system according to claim 1 in which said connecting means is adapted to render said impedance substantially purely resistive at one frequency substantially less than frequency $2f$ and at one or more additional frequencies some or all of which may be less than or greater than the said one frequency.

3. A radio aerial system according to claim 2 in which at least one of said additional frequencies lie within the range of from $0.5f$ to $3f$.

4. A radio aerial system according to claim 1 in which said connecting means is adapted to render said impedance substantially purely resistive at or near frequency f and in which a gap is provided in the aerial element substantially opposite the position at which said connecting means joins said aerial element.

5. A radio aerial system according to claim 4 in which said connecting means is adapted to render said impedance substantially purely resistive at or near frequency f and at one or more frequencies lying within the range of from $3f$ to $5f$.

6. A radio aerial system according to any one of the preceding claims in which a switched gap is provided in the aerial element substantially opposite the position at which said connecting means joins said aerial element.

7. A radio aerial system according to any one of the preceding claims in which said circuit comprises an inductance.

8. A radio aerial system according to claim 7 in which said inductance is provided with a pick-up coil for the coupling thereof to the signal translating device.

9. A radio aerial system according to either of claims 7 or 8 in which the circuit comprises an inductance having a capacitance in parallel with at least a part thereof.

10. A radio aerial system according to any one of claims 7 to 9 in which the circuit comprises a pair of inductances connected together by an intervening capacitance.

11. A radio aerial system according to any one of claims 7 to 10 in which the said circuit comprises an inductance and a capacitance, at least one of which is variable, connected together in parallel and two additional inductances, one pair of ends of which is connected to the termials to the said capacitance and the other pair of ends of which is interconnected by means of a further capacitance which is variable.

12. A radio aerial system according to any one of the preceding claims in which said connecting means contains one or more lumped reactance components.

13. A radio aerial system according to any one of claims 7 to 11 in which said connecting means comprises a transmission line at least one of the component conductors of which is connected via a lumped reactance to a point on the said inductance.

14. A radio aerial system according to claim 13 in which the said point is variable in position on the said inductance.

15. A radio aerial system according to any one of the preceding claims in which said connecting means comprises a trans-

mission line, the component conductors of which are interconnected by one or more lumped reactances.

16. A radio aerial system according to any one of the preceding claims in which said connecting means comprises a plurality of reactance networks and switching means adapted to connect a selected reactance network when required.

17. A radio aerial system according to any one of the preceding claims in which said connecting means comprises a reactance network containing at least one variable reactance component whereby the frequency at which said impedance is rendered substantially purely resistive may be varied continuously over a range of frequencies.

18. A radio aerial system according to any one of claims 1 to 11 in which said connecting means comprises a transmission line which is variable in length.

19. A radio aerial system according to any one of claims 1 to 11 in which said connecting means comprises a reactance component in the form of a short circuited length of transmission line.

20. A radio aerial system according to claim 19 in which said connecting means comprises a plurality of short circuited transmission lines and switch selecting means therefor.

21. A radio aerial system according to any one of claims 1 to 11, 19 or 20 in which the connecting means comprises a tuned transmission line and the circuit means includes a non-resonant transmission line.

22. A radio aerial system according to any of the preceding claims having a plurality of elongated loop aerial elements assembled and operable in combination to provide directional sensitivity.

23. A radio aerial system as claimed in claim 22 comprising two elongated loops mounted mutually crossed, operable separately and/or in combination.

24. A radio aerial system according to any one of claims 1 to 22 in which at least one aerial element is provided with a reflector and/or a director.

25. A radio aerial system according to any one of the preceding claims in which at least one aerial element is in the form of an elongated loop having more than 2 conductors running substantially continuously between its extremities.

26. A radio aerial system according to claim 25 in which said at least one aerial element is in the form of two elongated loops having corresponding gaps on one pair of sides which are connected together and in which on the other pair of sides, loops placed side by side said elongated one loop only is provided with a feed point while the other is continuous.

27. A radio aerial system according to any of the preceding claims wherein the conductor(s) of one or more of the at least one elongated loop(s) forming the aerial element is/are attached to, or embedded in, or mutually supported or separated by, insulating material which extends partially or wholly across or throughout the area and space encompassed by or separating said loop or loops or which, relative to said conductors lies or is formed substantially in the manner or manners adopted in ribbon or webbed feeder construction.

28. A radio aerial system substantially as hereinbefore described with reference to the accompanying drawings.

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Chartered Patent Agents,
Agents for the Applicant.

Leamington Spa: Printed for Her Majesty's Stationery Office, by the Courier Press.—1953. Published at The Patent Office, 25, Southampton Buildings, London, W.C.2, from which copies may be obtained.

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SHEET 1

FIG.1.

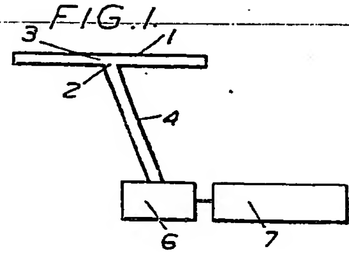


FIG.2.

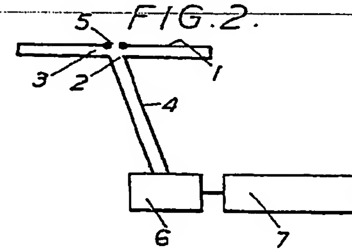


FIG.3.

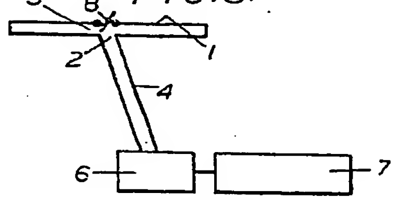


FIG.4.

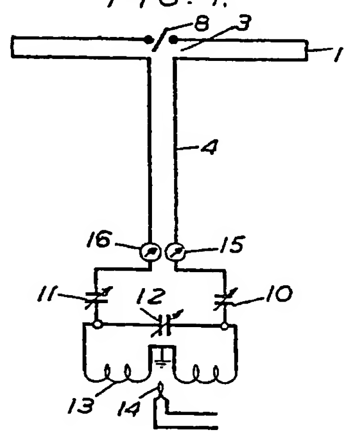


FIG.5.

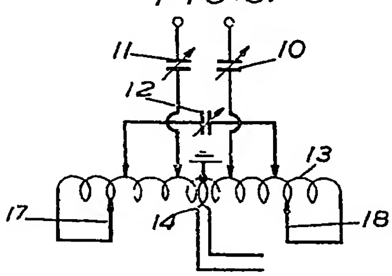


FIG.6.

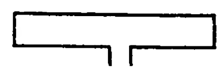


FIG.7.

FIG.8.

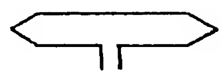


FIG.9.

FIG.10.

FIG.11.

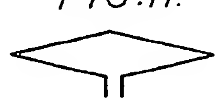


FIG.12.

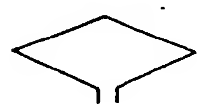


FIG. 13.

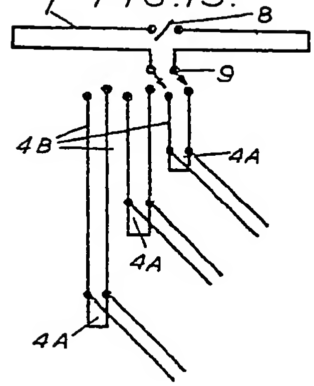


FIG. 14.

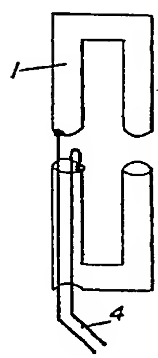


FIG. 15.

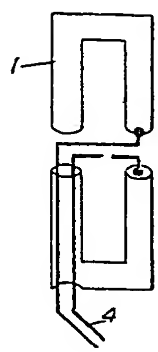


FIG. 16.

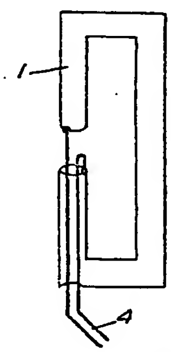


FIG. 17.

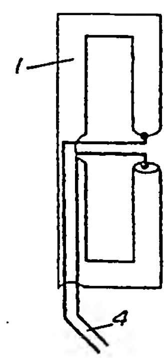
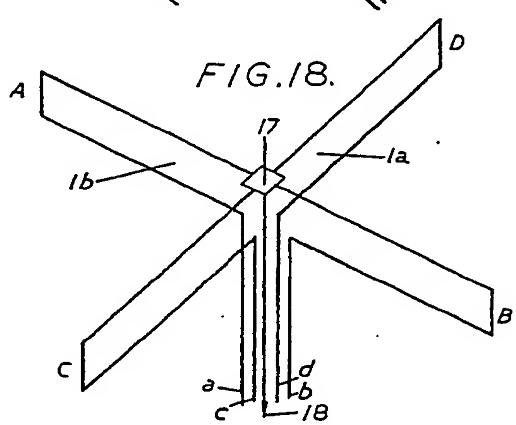


FIG. 18.



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SHEETS 2 & 3

FIG. 19.

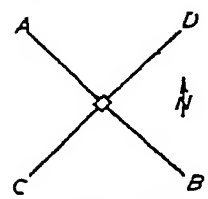


FIG. 20.

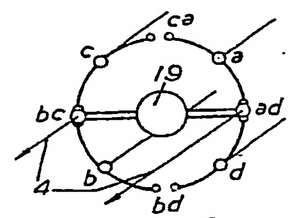


FIG. 21.

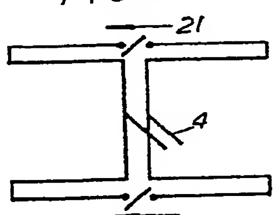
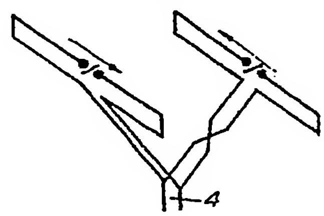


FIG. 22.



17.

FIG. 23.

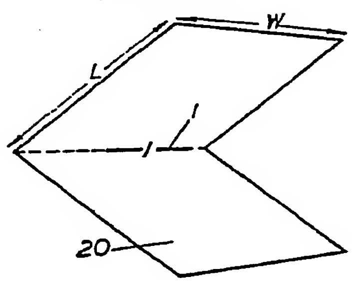


FIG. 24.

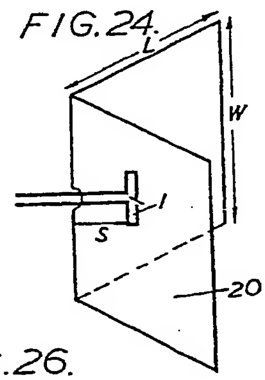


FIG. 25.

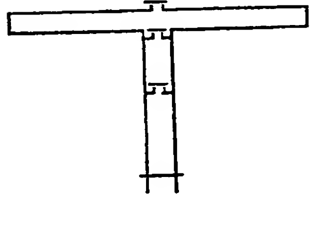
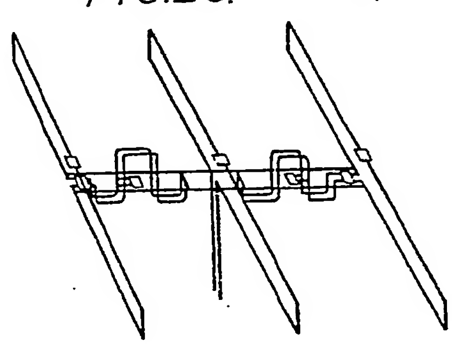


FIG. 26.



692,692 COMPLETE SPECIFICATION
5 SHEETS
This drawing is a reproduction of the Original on a reduced scale.
SHEETS 2 & 3

FIG.13.

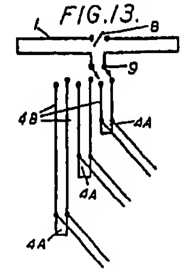


FIG.14.

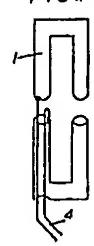


FIG.15.

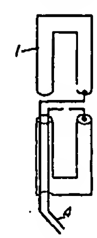


FIG.16.

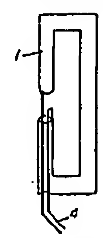


FIG.17.

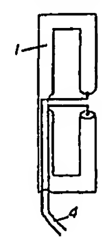


FIG.18.

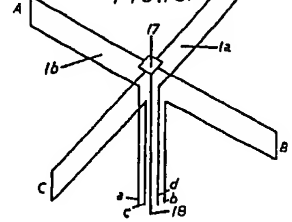


FIG.19.

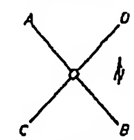


FIG.20.

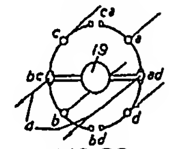


FIG.21.

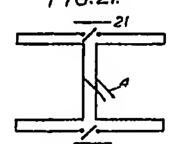


FIG.22.

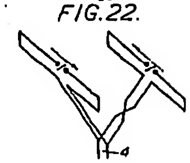


FIG.23.

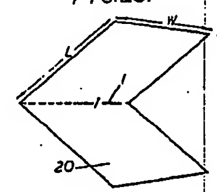


FIG.24.

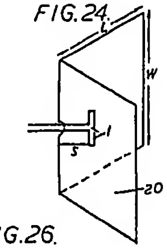


FIG.25.

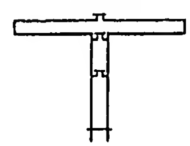


FIG.26.

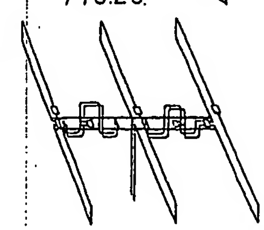


FIG.27.

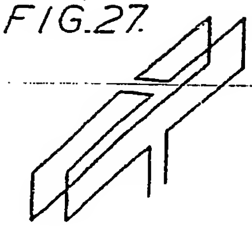


FIG.28.

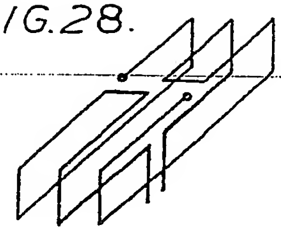


FIG.29.

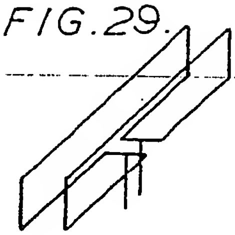


FIG.30.

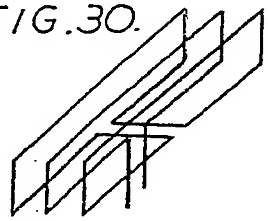


FIG.31.

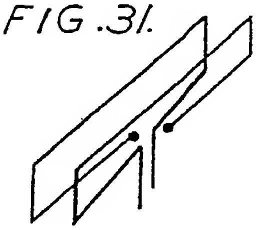


FIG.32.

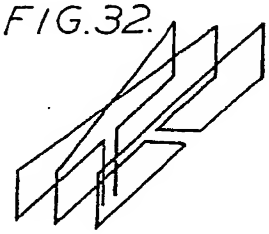


FIG.33.

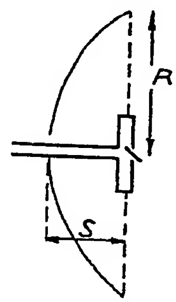


FIG.34.

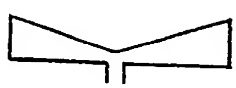


FIG.35.

FIG.36.

FIG.37.

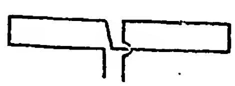
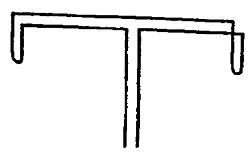


FIG.38.

FIG.39.



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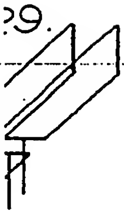

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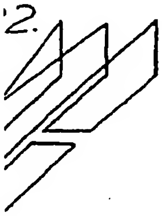


FIG. 40.

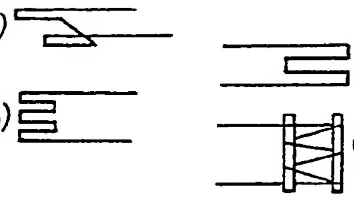


FIG. 41.

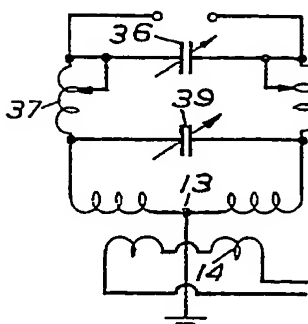
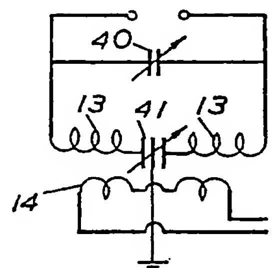


FIG. 42.



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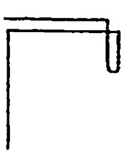
39.



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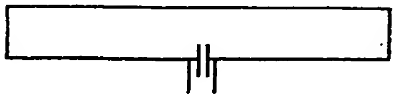

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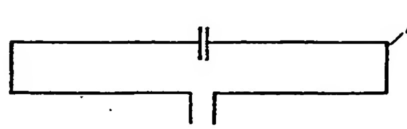


FIG.27.

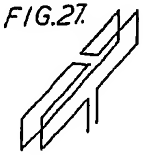
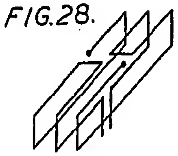


FIG.28.



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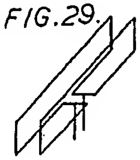

FIG.30.

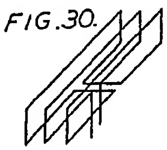

FIG.31.

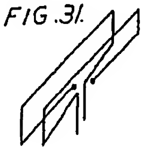

FIG.32.

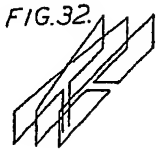

FIG.33.

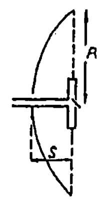

FIG.34.

FIG.35.

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FIG.38.

FIG.39.

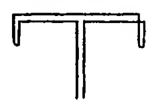

FIG.40.

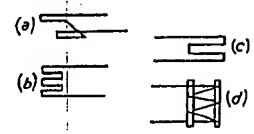

FIG.41.

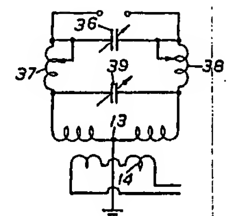

FIG.42.

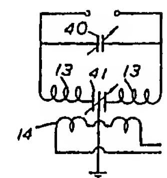

FIG.43.

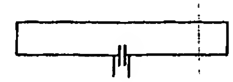

FIG.44.